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Linking subsurface temperature and hillslope processes through geologic time

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Many periglacial hillslope processes - physical, chemical, and biological - depend on subsurface temperature and water availability. As the subsurface temperature field varies both in space and through time over many scales up to climate cycles, the dominant processes of mobile regolith production and transport and the rate at which they act will vary. These processes include the chemical weathering of minerals, cracking of rocks through frost action and tree roots, presence and impact of vegetation on soil cohesion, location and activity of burrowing and trampling animals, frost creep, and solifluction. In order to explore the interplay between these processes across a landscape over the geologic timescales on which such landscapes evolve, we explore the effects of slope, aspect, latitude, atmosphere, and time before present on the expected energy balance at the surface of the earth and the resulting subsurface temperature field.

We begin by calculating top-of-atmosphere insolation at any time in the Quaternary, honoring the variations in orbit over Milankovitch timescales. We then incorporate spatial and temporal variations in incoming short-wave radiation on sub-daily timescales due to elevation, latitude, aspect, and shading. Outgoing long-wave radiation is taken to depend on the surface temperature and may be modified by allowing back-radiation from the atmosphere. We then solve for the subsurface temperature field using a numerical model that acknowledges depth-varying material properties, water content, and phase change.

With these tools we target variations in regolith production and motion over the long timescales on which periglacial hillslopes evolve. We implement a basic parameterization of temperature-dependent chemical and physical weathering linked to mobile regolith generation. We incorporate multiple regolith transport processes including frost heave and creep. Our intention is not to parameterize all operative processes, but to include sufficient detail to identify how the different processes interact. We address questions that include: What governs contrasts in process rate on pole-ward vs. equator-ward slopes? Under what conditions should we expect temporal transitions between transport-limited and weathering-limited erosion? How does the legacy of past climate impact later hillslope activity?